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A Permanent Type of Ditch Construction

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MEMPHIS has carried on an intensive malaria mosquito control program for 15 years and all money budgeted for this work has been spent on the control of the *Anopheles* breeding in the ditches and bayous. A total of approximately \$140,000, excluding administrative and premise inspection costs, has been expended by the city during the years 1920 to 1934 inclusive, starting with an allotment of about \$4,000 a year for a city of 24.3 square miles and a population of 162,351; and increasing to an allotment of about \$13,000 a year for a city of 48.2 square miles and a population of 268,358. Until 1930, this money was expended solely for oiling all ditches once every 10 days, or as nearly every 10 days as is possible, with a small amount of ditching and cleaning of water courses during off seasons. In 1930 a small cooperative experimental project of lining about 1,000 feet of ditch with concrete was carried out at the suggestion of J. A. LePrince, with the U. S. Public Health Service furnishing the material and the city furnishing the supervision and labor. All of this ditch is still intact and is satisfactory as a concrete lining. This experimental project was installed in sections using

different mixes and thicknesses to determine the most economical for general use in Memphis.

In ditching for malaria mosquito control, the ideal section of ditch is V shape with a narrow U shape center ditch within the larger main ditch. Flat bottoms, especially of dirt or in concrete culverts encourages meandering flow with frequent dams and pools. Permanently lined ditches with sodded banks prevents the ditch from scouring deeper, wider, and irregularly, eliminating the every 10 day routine oiling work. Repeated regrading, cleaning, and oiling of unlined earth ditches has proved a constant and endless task. Properly lined and stabilized ditches show a greater first cost, but are ultimately less costly and far more effective as a control measure. The maintenance cost of the ditch is practically eliminated, which in this day of intensive public building, is a very important point to a city. The problem of flood control and elimination of erosion and loss of public and private property, are other important benefits realized. With this in mind, in the C.W.A. ditching work in Memphis and later in the E.R.A. work, the concrete lining of ditches was stressed.



FIGURE I—Royster Bayou through a residential section at Galloway Avenue and Avalon Street, before work was done

J. A. LePrince, known to all yellow fever and malaria control workers for his outstanding leadership in this field from the first campaigns in Havana, Cuba, and the Panama Canal, to the present time, has been urging and assisting the Memphis Health Depart-

ment in this work which promises to broaden and make far more effective our malaria mosquito control program.

Out of the rush and tension of our C.W.A. struggle to accomplish as much as possible with a large force of men with hastily selected and untried or un-



FIGURE II—Same as I after lined with broken concrete pieces for walls and bottom with cement grouting and sodded banks

tested relief supervision, with adverse weather conditions and with the problems of getting labor and materials, transportation and equipment to mesh in together, approximately 6 miles of 18" concrete lining was placed in the bottom of straightened ditches. An effort was made to sod and stabilize these concrete lined ditches as the work proceeded, but only approximately 2 miles of the 6 was sodded.

In all cases, without exception, where the concrete lining was installed and the banks were sodded, there were no failures and no follow-up repair work was necessary. Sodding should in all cases immediately follow the completion of the concrete lining. In other words, with a concrete lining by itself without protection such as is afforded by sod at the edge of the concrete lining, the swift flowing water in the narrow bottom of the ditch will erode the banks and undermine the concrete lining. Erosion may also be caused by water running down the bank from the top and forming little channels which will eventually cause erosion, especially at the edge of the concrete lining. Except in special cases, this erosion can be prevented by the use of Bermuda sod. In addition, sharp bends, tree roots and other obstructions cause eddies and churning and hence are important points to protect by removing or by special treatment to prevent erosion. A comparison of unit cost of concrete or rip-rap or sod when used to stabilize the banks of the ditch above the central concrete lining, indicates that with the use of sod, there is no material cost, while with the use of rip-rap and cement grouting, the material cost is 1 cent per sq. ft. and for concrete the cost is about 10 cents per sq. ft. In addition to protecting the sides and the bottom of the ditches to prevent erosion, it is advisable to incur additional expense in many cases to straighten the ditches, as this pro-

vides for quick run-off which is beneficial from a flood control standpoint and at the same time minimizes the erosive action of the water as it goes around the sharp bends.

LOCATION AND DESIGN

A preliminary survey by walking over the existing ditch will determine whether any changes should be made in the course or line of the ditch. If any changes are considered advisable or necessary, a more detailed survey of the ditch and territory adjacent to the existing and the proposed new location should be made to determine the location of the ditch, property lines, houses, culverts, sewers, water pipes, etc. A map and profile should be drawn showing the actual location and elevations as well as a map and profile of the proposed ditch together with the elevations of all underground piping. In some cases the property lines will govern largely the course of the ditch, and in all cases easements should be secured from the owners of property affected by the changes.

The grades, dimensions of section, the location and the course or line of each ditch depend on the drainage area or watershed it serves. This area has already determined or influenced the size, grade or elevation and location of bridges and culverts through actual field data and calculations, or through estimates based on experience when this data is not available. Subdivision developers have changed the course of drainage oftentimes in order to lay off as many lots as possible. After selling these lots to many individuals, some of whom build soon after their purchase, it soon becomes impossible to straighten or change ditch locations even though they may follow a crooked course around lot corners and buildings. It is important, however, to study the possibility of changing the existing zig-zag course of many ditches to a shorter,

TABLE I
GUIDE FOR DESIGN OF LINED DITCHES
CITY OF MEMPHIS DEPARTMENT OF HEALTH

Culvert Dimensions		Ditch Dimensions						Culvert Dimensions		Ditch Dimensions					
Depth	Width	Bottom	Top	Slope	A.d.	A.c.		Depth	Width	Bottom	Top	Slope	A.d.	A.c.	
2	2	1.5	3.5	½-1	5	4		5	4	1.5	6.5	½-1	20	20	
2	3	1.5	4.5	¾-1	6	6		5	5	1.5	8.5	¾-1	25	25	
2	4	2.0	6.0	1-1	8	8		5	6	1.5	10.5	1-1	30	30	
2	5	3.0	7.0	1-1	10	10		5	7	2.0	12.0	1-1	35	35	
2	6	4.0	8.0	1-1	12	12		5	8	3.0	13.0	1-1	40	40	
2	7	5.0	9.0	1-1	14	14		5	9	4.0	14.0	1-1	45	45	
2	8	6.0	10.0	1-1	16	16		5	10	5.0	15.0	1-1	50	50	
3	3	1.5	4.5	½-1	9	9		6	5	1.5	8.5	¾-1	30	30	
3	4	1.5	6.5	1-1	12	12		6	6	1.5	10.5	¾-1	36	36	
3	5	2.0	8.0	1-1	15	15		6	7	1.5	12.5	1-1	42	42	
3	6	3.0	9.0	1-1	18	18		6	8	2.0	14.0	1-1	48	48	
3	7	4.0	10.0	1-1	21	21		6	9	3.0	15.0	1-1	54	54	
3	8	5.0	11.0	1-1	24	24		6	10	4.0	16.0	1-1	60	60	
4	4	1.5	6.5	¾-1	16	16		6	11	5.0	17.0	1-1	66	66	
4	5	1.5	8.5	1-1	20	20		6	12	6.0	18.0	1-1	72	72	
4	6	2.0	10.0	1-1	24	24		8	8	1.5	14.5	¾-1	64	64	
4	8	4.0	12.0	1-1	32	32		8	10	2.0	18.0	1-1	80	80	

1. Minimum of 18" bottom. 2. Limits of slopes: Minimum ½ to 1. Average 1 to 1. Maximum 1½ to 1. 3. Three or 4 culverts or bridges should be used in establishing necessary area of ditch. In going down stream area should never decrease but increase according to increased run-off.

straighter ditch and also wherever possible to eliminate the sharp bends which interfere with the flow of water in the ditch and create eddies and scouring.

In designing the proper section of ditch for the concrete lining with sodded banks, certain limiting values are used. The most satisfactory slope used in Memphis is a 1½ horizontal to 1 vertical. The minimum width lining is 18". The area of the lined ditch should be greater than, or equal to the area of the culvert it receives its water from, if this culvert or bridge is built to carry a definite run-off already figured for the ditch. In other cases a number of culverts and bridges should be measured and the size of ditch figured to carry at least the volume of water now carried by the existing structures. In all cases, if possible, a uniform section should be kept throughout the length of each ditch. In general, linings should be U shape to carry the dry weather flow. In wide ditches a narrow U shape section can be installed in the center with sloping rip-rap sides for the rest of the width

of the ditch. The maintaining of a uniform grade and section will minimize changes in velocity and the resultant dropping of sediment and thus prevent the forming of dams and leaving pools of water.

Table I has been computed as a guide in deciding on the proper width and slope of concrete lined ditches. In many cases, however, the actual width of a ditch may necessitate a wider bottom than shown in the table. The table is used only as a guide and to insure that all V shaped lined ditches are large enough to carry the run-off.

EXCAVATIONS

Grade and slope stakes should be set for the rough or preliminary excavation. On straight ditches the stakes should be set 50' apart, on curves about every 25' or less, and on sharp curves about 10' apart. Cutting to these stakes will bring the ditch to within a few inches of the finished ditch. Better alignment and a more satisfactory completed ditch from all standpoints can be obtained if a trench the width

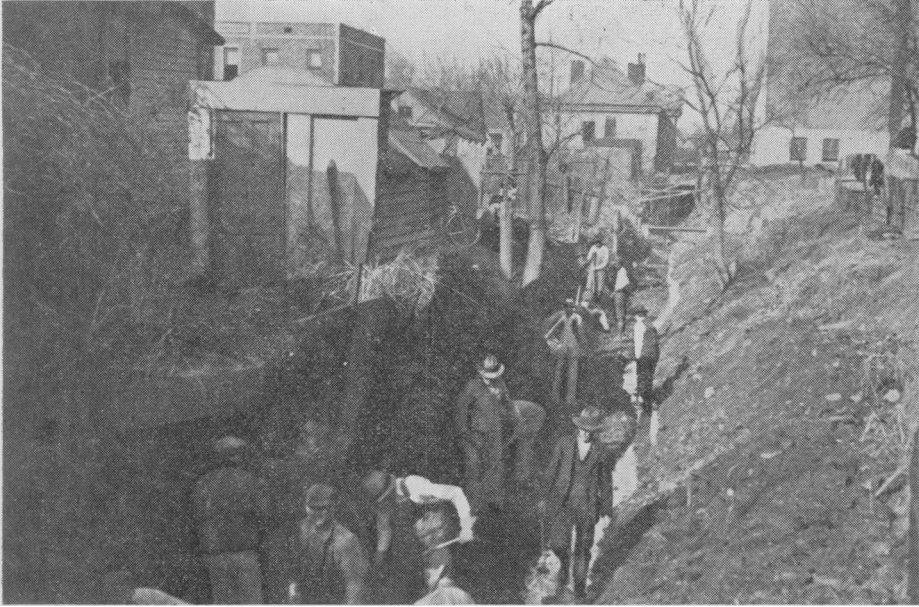


FIGURE III—Section of Madison Heights Bayou looking north toward Jefferson Avenue.
Note: Caving frame supports an old shed before much work done.

of the bottom of the ditch is dug to line and grade and then the sides sloped rather than try to do sloping

along with the other excavation. This does not apply to large ditches where “step excavation” is the best pro-



FIGURE IV—Same as III after lined with rip-rap and banks sodded

cedure. At this point the final grade stakes should be reset to finish the excavation. The top of the center line grade stake should be driven to the concrete finish grade, and the side and slope stakes should also be set to the concrete finish grade. The side stakes, that is, the ones at the outer edge of the concrete lining should be set about 6" above the center line stakes on the 18" and 24" lining. The ditch bottom is cut to 2" or 3" (the thickness of the concrete lining) below the top of the stakes. This final excavation should be done by experienced ditchers to insure a uniform bottom to grade so as to have uniform thickness of concrete. If the lining is too thin it is weak: if it is too thick it wastes concrete and money; if nails are driven into the top of the stakes and a cord pulled taut between stakes, it assists in cutting a uniform width and depth, and the cords can be used also as a guide in placing the concrete. The outside of curves is elevated just as is done in building a highway.

CONCRETE LINING

In mixing the concrete for the lining, a few fundamental rules should be observed to get the best at the least cost. A lean mix and as thin a lining as will last is, of course, the most economical. We are now using a 2" thick lining with a 1:3:5 mix using a minimum amount of water just to make the mix workable to keep the water-cement ratio low. The 18" lining has about a 6" drop from the edges to the center line. When possible to buy or borrow a concrete machine mixer, the work can be speeded up.

If the mixer is placed halfway between, or say 200' on long stretches from the upper end of the ditch and enough material placed at this point to complete the whole stretch or the first 400', time will be utilized to best advantage in not having to handle the

material and equipment any more than is necessary. The ditch would be poured from the upper end to the downstream end. If the mixer is a large one, two laying crews can be used, with each crew laying 200' in two sections at the same time.

A chute can be arranged to slide the concrete direct into wheelbarrows from the mixer. Runways placed on the bottom of the ditch, consisting of 2" boards will prevent the cutting or muddying up of the ditch bottom, as the concrete is wheeled down the ditch to where it is being placed. A thin lining should not be poured on a muddy bottom. Although expansion joints were not used in much of the C.W.A. lining work and there have been no subsequent failures, we are now using about 6 sheets of 2 ply tar paper for joints about every 50'.

On steep grades, especially where the lining is placed on a fill, or where for any other reason the water might be allowed to run under the lining, key walls about every 200' should be built at right angles and extending under the lining into a solid foundation to stop the flow of water with weep holes on the upstream side to provide outlet for the water after the rain, to seep up onto the lining. (See sketch of key wall).

In some cases where sod was not immediately placed at the edge of the lining, scouring was worse when the edge of the lining was rough. If the sod was immediately placed, the rough edge did not seem to cause any scouring.

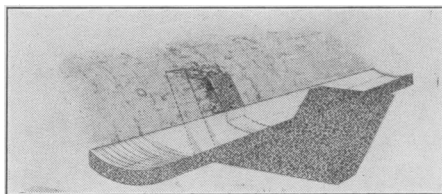


CHART I—Sketch of Key Wall



FIGURE V—Section of Madison Heights Bayou looking north toward Court Avenue before cleaning and rip-rap work done

Forms can be used without losing much time making it possible to get a smooth edge. Care should be taken to prevent any honeycombing of the concrete

at the edge and the top edge is being slightly rounded.

Even though the lining is not usually subjected to any great pressure, the

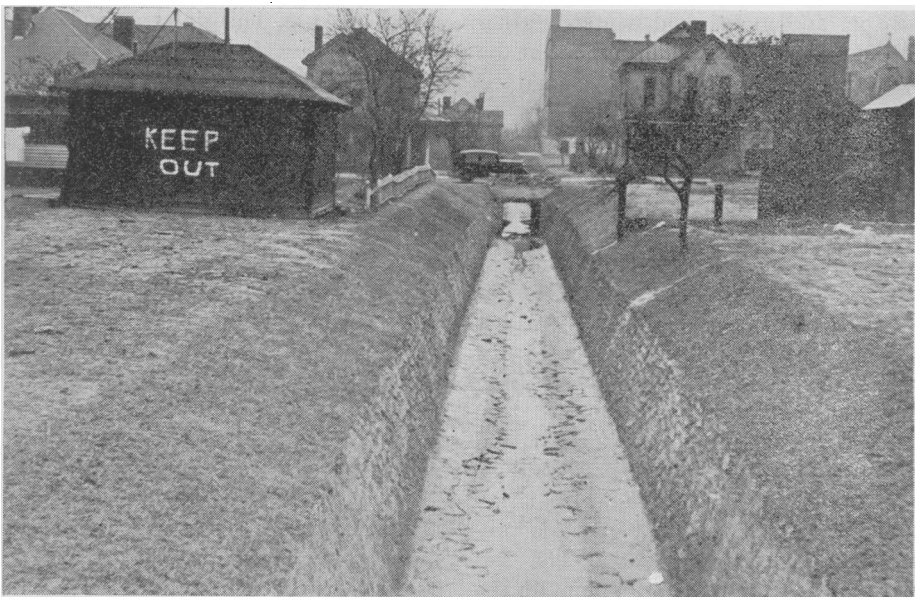


FIGURE VI—Same as V after lining bottom and sides and sodding banks

lining should not be allowed to dry out for a day or so, especially in the dry weather, in order to cure properly and prevent scaling off, pitting, or disintegration later on. No reinforcing has been used. As already emphasized, the sod should now be laid on the banks without delay.

SODDING

In sodding, the operation is divided into two steps with a sod cutting and loading crew of 8 to 10 men and a sod laying crew of 2 to 3 men. Sod is cut in strips of approximately 10" x 12" x $\frac{1}{2}$ " to 1" thick. Only thick and pure Bermuda sod is used. If $\frac{1}{2}$ " to 1" thick sod is cut and laid, the roots will grow 2" within a few weeks and thus get a firm bull-dog grip on the bank and withstand heavy flood rains, while 2" or thicker sod takes many days before the roots will extend themselves and grip the bank. If the sod has been cut too thick, heavy tamping after laying will tear loose the sod and roots and encourage more rapid growth of new roots.

Sodding is done both in hot summer weather and in the cold winter weather as the roots will grow even when the top grass does not. The bank should be dressed to a uniform grade and 1" below the top edge of the concrete lining to support the blanket of sod. The bank should not be cut below the top edge of the lining until the sod is to be laid, as the overhanging slope or bank is a protection against erosion at the concrete lining edge until the sod is laid. If the sod is being laid on a dry bank, the slope should be wet down thoroughly before laying.

As soon as the sod is placed and well tamped with shovels, it should be covered with $\frac{1}{2}$ " of earth which is accumulated from the bank as it is prepared to receive the sod. The sod blanket is extended to the top of the bank and over the top for several

inches. We have had very little success with spot sodding, and even when used only on the upper half of the banks, the repairing of the upper half for sodding after damaging rains has convinced us that we should do a complete job at first.

On deep ditches where a $1\frac{1}{2}$ to 1 slope would give a wide top, the bottom width may be increased and a rip-rap wall on a $\frac{1}{2}$ to 1 slope installed to a height of 3 or 4' and then a $1\frac{1}{2}$ to 1 sodded slope for the rest of the bank will result in a narrower top and still maintain the most desirable slope, $1\frac{1}{2}$ to 1 for dirt or sodded banks.

RIP-RAPPING

The term rip-rapping has been used in our ditching work to mean the use of broken pieces of concrete or stone with one smooth surface, as from a concrete sidewalk, floor, porch, wall or street. Old asphalt has been used but its tendency to crumble when not in use supporting traffic, has influenced us to use it for fill only. Some of our early work was with asphalt, and in years to come we will learn more about its possible use. This rip-rap may be used in big ditches for bottoms and walls or may be used on the sides of a small center concrete lining to increase the bottom width while having a concrete center lining to carry the dry weather flow. Again the rip-rap can be used in many cases to narrow a section of ditch to secure a uniform width, by building a wall and filling behind it. Shallow filling and sodding in place of a wall may be done if the existing bank is first spaded up or turned over to make a good bond between the existing and the new bank just as a roughening of an old concrete surface is necessary to secure good bond with a new layer of concrete. The wall need not be brought to the top of the bank if the bank is sloped and sodded above the wall, with the sod extending over the

top of the wall to the inside edge. In other places shade, due to bridges or trees, may make it necessary to use rip-rap in place of Bermuda. Walls may be used on sharp bends where scouring action is particularly severe.

As indicated above, some of the ditch lining installed by the C.W.A. about a year ago, was not sodded, and in cases considerable scouring and washing has taken place necessitating filling and widening the bottom and building side walls.

In constructing a complete rip-rap lining of walls and bottom, the walls are installed first. It is important in getting a uniform alignment to use slope stakes for the top and bottom and slope of the wall, usually $\frac{1}{2}$ horizontal to 1 vertical. The wall must be carefully constructed to stand and a solid foundation or footing is of first importance. The wall is begun a foot or more, if necessary, below the grade of the ditch to reach a firm foundation of dirt. The pieces of rip-rap are placed with the flat side up, not parallel to the bottom of the ditch, but perpendicular to the slope of the bank, the straightest edge is placed out as a part of the wall surface. At sections of ditch, where the velocity or scouring is severe the wall joints may be filled by slapping and brushing a 1:4 mix of cement mortar into them. Weep holes are left about every 25' to allow water entrapped behind the wall, especially in fills, to seep out into the ditch.

The bottom is built up or cut to a grade so that the flat face of the rip-rap when placed will meet the final grade line of the ditch lining. If the bottom can be lined when dry, care should be taken to have the dirt bottom firm and well tamped when fill is necessary. If the bottom is lined when the ditch is carrying a flow of water, rip-rap should be used to fill holes and a gravelly or coarse material should be used for fill with the voids filled with

dirt. As the rip-rap is laid on the bottom, each piece is placed carefully just as in building a wall, and tamped with the dirt bottom scraped away or added to make the flat piece of rip-rap lay flat and firm and to grade. A man on the bank slides pieces of rip-rap down to a man in the ditch who passes each piece to the rip-rap layer as he needs it. A half dozen or more crews may be placing rip-rap at the same time.

After all of the rip-rap has been placed, a finish man with a helper goes the entire length of the section, tamping and testing each piece to be sure all are firmly placed and to grade. On a wide bottom, a straight edge is used from the center line grade to the side of bottom grade to insure a uniform bottom with a slope to the center line for dry weather flow and no low or high places to cause water to stand.

Gravel and sand can then be brushed into the space between the pieces and tamped to "key up" the lining. A 1:4 mix of cement mortar is then brushed over and into the lining joints.

The sod should be placed on the dirt bank above and over the top of the wall and extend from the inner edge of the ditch walls to several inches over the top of the bank. It is important to tamp and settle the dirt-fill behind the wall to prevent later settling and slipping of the wall in places. If broken stone is used for fill, the voids should be filled with dirt and tamped as the fill is made and then covered with a blanket of sod.

In general, the cost of the concrete lining has run about 10 cents per square foot for material, including the cement, sand and gravel, while in the rip-rap work the only material purchased is cement and sand for grouting, as the broken concrete has been free for the hauling, and this has run about 1 cent per square foot. All sod used has been free. Because of the use of relief labor, no attempt has been made to

show unit costs of excavation or laying concrete, rip-rap, or sod. A total of 5.8 miles of ditches have been stabilized to date and a proposed project is now being submitted for lining and sodding 16.6 miles with an 18" to 24" concrete lining with sodded banks. Rip-rap will be used for walls, etc., where necessary.

SUMMARY

Lining of ditches with concrete and sodding, or with rip-rap material and sodding is being constructed in Mem-

phis with relief labor. A large force of common labor can be used with a small outlay of materials and equipment with a lasting and important influence on health. The maintenance cost is low, flood damage by erosion and loss of public and private property is stopped.

Certain lessons have been learned in constructing approximately 6 miles of ditch lining.

NOTE: The photographs included in this article were made by M. F. Carter, Memphis Health Department.

Pine Board Gavel

WHEN next year's meeting of the Western Branch of the American Public Health Association is called to order at Vancouver, B. C., Dr. W. F. Cogswell of Helena, new president of the organization, will rap sharply on the table with the official permanent gavel of the group—a common piece of Montana yellow pine board.

Rising to an emergency at this year's meeting in Helena in July, Dr. W. P. Shepard of San Francisco, secretary of the association, hurriedly found the piece of board and offered it to Dr. W.

H. Brown of Palo Alto, Calif., who was presiding.

The improvised gavel was used at most of the convention sessions and, after Dr. Brown had employed it for the final time during his presidency, Dr. Shepard had the out-going president autograph the board, which was turned over to Dr. Cogswell with instructions to have it available at next year's convention, as then and there it was proclaimed the official gavel of the organization for all future sessions. —*Montana Record Herald*, July 5, 1935.